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Network-assisted Smart Access Point Selection for Pervasive Real-time mHealth Applications

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Abstract

Due to the fast evolution of wireless access networks and high-performance mobile devices together with the spreading of wearable medical sensors, electronic healthcare (eHealth) services have recently started to receive more and more attention, especially in the mobile Health (mHealth) domain. The vast majority of mHealth services require strict medical level Quality of Service (QoS) and Quality of Experience (QoE) provision. Emergency use-cases, remote patient monitoring, tele-consultation and guided surgical intervention require real-time communication and appropriate connection quality. The increasing significance of different overlapping wireless accesses makes possible to provide the required network resources for ubiquitous and pervasive mHealth applications. Aiming to support such use-cases in a heterogeneous network environment, we propose a network-assisted intelligent access point selection scheme for ubiquitous applications of Future Internet architectures focusing on real-time mobile telemedicine services. Our solution is able to discover nearby base stations that cover the current location of the mobile device efficiently and to trigger heterogeneous handovers based on the state and quality of the current access network. The solution is empirically evaluated in Wi-Fi networks used by real-life Android mobile devices and we observed that the scheme can improve the quality of mHealth applications and enhance traffic load balancing capabilities of wireless architectures.

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Keywords: Network-assisted handover; context-awareness; multi-criteria decision engine; DDE; NIS; Android; real-time mHealth services; multi-sensor based patient monitoring; ubiquitous tele-consultation; Body Area Network

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1. Introduction

Nowadays, electronic Health[1] services have been receiving more and more attention thanks to the substantially increasing number of high-performance computing devices interconnected with medical sensors/diagnostic systems via heterogeneous network technologies.

Mobile Health[2] is a sub-segment of the eHealth field, aiming to use mobile devices, wearable or built-in sensors with Body Area Networks and the widest scale of wireless communication technologies to enhance traditional medical services. Advanced mobile technologies play an increasingly important role in health systems especially in scenarios of tele-consultation/telediagnosis and mobile patient monitoring. Naturally, mHealth services require strict, medical level QoS and QoE provision[3]. The real-time use-cases of mHealth services such as remote mobile patient monitoring, telecare and remotely guided surgical intervention require even higher guarantees (e.g., small delay and jitter, fast response time, and low packet loss). Many mHealth scenarios rely on wearable body vital (e.g., ECG, heart rate monitor, ultrasound) or built-in sensors of smartphones (e.g., high-resolution camera and gyroscope). The highly varying characteristics of different mHealth applications in means of the required network resources, QoS/QoE requirements invoke elaboration of advanced network management architectures. These facts motivated us to design and implement a network-assisted wireless access network selection framework for mHealth services, which is able to select the appropriate available access network using a multi-criteria decision engine. The proposed engine relies on the Distributed Decision Engine[4] (DDE) and the Network Information Service[5] (NIS) providing both static and dynamic parameters of the available networks. Our current solution is implemented for Wi-Fi networks, which is presented and evaluated in this paper. The proposed architecture provides an efficient environment for medical quality data transmission in various mHealth scenarios.

The rest of paper is organized as follows. In Section II we present the related work on the existing solutions of efficient mobility management schemes for real-time mHealth services/applications. Section III introduces our network-assisted smart access network selection scheme for real-time multi-sensor based patient monitoring and tele-consultation implemented on Android devices and Wi-Fi access. Also the overall management solution and the proposed multi-criteria decision engine for mHealth services are depicted in details. Section IV presents the validation of the proposed framework performed on a real-life, Android-based testbed environment. In Section V we conclude the paper and describe our future work.

2. Background and Related Work

The substantially increasing deployment of small cell access techniques, such as WLANs, pico- and femtocells in 3G/4G architectures result in a highly heterogeneous network environment with many overlapping wireless coverages. This provides also mobile healthcare applications with more alternatives to find sufficient network resources and also enables ubiquitous health monitoring and control functions. The mHealth field covers fitness trackers, weight loss and exercises applications tele-consultation, patient monitoring, guided diagnosis and surveillance (e.g., guided ultrasound), remote surgery etc.[6]. Mobile patient monitoring is a special type of mHealth aiming to measure, collect and transfer data of biovital signals (e.g., ECG, EMG, blood pressure, blood glucose, body temperature, heart rate and respiration rhythm) provided by wearable medical sensors from the patients toward the hospital or other healthcare/emergency centre[7]. Authors[8] categorize the remote patient monitoring systems, try to identify the most important mHealth stakeholders and their requirements to design a generic system architecture. In [9], a comprehensive report is presented about the evolution of mobile healthcare. The summary includes extensive desk research and 20 in-depth interviews from healthcare providers and payers, technology and telecommunications companies and industry organizations.

Ubiquitous tele-consultation is used to create an environment for preliminary consultation between patients and nurses/doctors associated with a possibility of sending medical data of patients, such as ECG and other medical examinations results, CT scans, MRI images and ultrasound using heterogeneous wireless networks[10]. J. Williams et al.[11] designed and implemented a videoconference-based tele-consultation system, which aims at surveying efficiency and patient satisfaction of these applications. The benefits of tele-consultation services reduce the overhead costs of consultation, while also make appointments quicker and allow doctors to be able to conveniently access patients who may be at far distance from the hospital. However, such services require pervasive networking with the highest possible QoS/QoE. Essential techniques for such requirements are mobility triggering, cross-layer signalling, location-based mobility, and efficient support of heterogeneous networks. The literature on access network selection schemes and vertical handover (VHO) solutions is extensive, many papers introduce Wi-Fi access point selection mechanisms (e.g. [12, 13, 14]). However, these approaches do not use network-assisted network discovery and selection entities and do not include real-life smartphone-based implementation for evaluation purposes. The basic idea of the event based signalling framework used in this paper is based on Triggering Frame-work proposed by Mäkelä et al.[15]. It also allows flexible event delivery between any network entities in the networks in a register-subscription manner. Triggering Framework has been used for network quality based mobility management by Luoto and Sutinen[16]. The authors monitor the Wi-Fi access point load for triggering handovers in the mobile device acting as a video client. However, they do not exploit information service for discovering the available target networks. Location-based mobility management with intelligent network selection has been studied, for example, by Pawar et al.[17], Bokor et al.[18] and Dutta et al.[19]. However, none of these solutions can provide coverage area based network information for mobile devices reliably through a service, which is available in the network for all users. The information service solution used in this paper is studied in [20,21] for optimizing the cell selection based on the coverage areas. In [22], the same information service solution is extended to the QoS/QoE scope where the coverages are represented as quality areas, instead of signal strength. Indeed, the literature of vertical handover mechanism is really extensive, however vast majority of papers cover theoretical approaches or analysis in simulated environment, the real-life implementation of multi criteria-based decision schemes integrated with smart and network-assisted mobility management architectures is less prevalent, especially in smartphone devices.

In our previous works we designed and implemented Mobile IPv6-based flow mobility management architecture and used it to optimize mHealth application provision. In [23] we proposed an Android-based testbed and demonstration environment for cross-layer optimized flow mobility mechanisms. In our previous work[24] we presented a client-based flow aware solution for heterogeneous Femtocell/Wi-Fi environments, which was placed later into the mHealth context to support real-time mHealth services[25]. However, our aforementioned solutions do not cover neither event based signalling system, nor location-aided and network-assisted mobility enhancements.

3. The Proposed Network-assisted Smart Access Point Selection Scheme

3.1. Overall architecture

Fig. 1 presents our Android Smartphone-driven architecture designed for pervasive real-time mHealth applications.

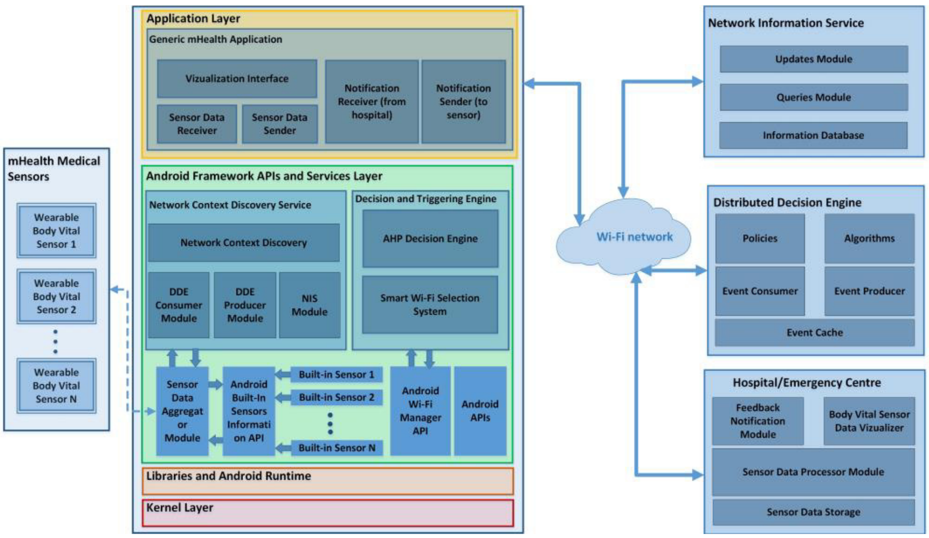

Fig. 1. The proposed network-assisted smart Wi-Fi selection architecture

3.1.1. Android Smartphone

Our customized Android device comprises four main functional blocks. The Sensor Data Aggregator module collects data from wearable biovital sensors and Smartphone-integrated general sensors, and sends the measured data towards a correspondent node, which is typically a hospital or an emergency centre. The sensor aggregator has been designed with a modular structure, thus we can add new sensors easily. Our experiments in this paper apply the data of three different sensors, namely a Samsung Gear Fit Smartwatch, a Zephyr HxM heart rate monitor and the built-in HD camera of a Samsung Note 3 Smartphone. The Network Context Discovery Service provides both static and dynamic information of the available Wi-Fi networks for the proposed decision engine. This module relies on the DDE and the NIS, as the main information sources for supporting the decision making. The Decision and Triggering Module selects the most appropriate Wi-Fi network for the mHealth application from the available WLANs, then configures and connects the smartphone to the selected network. The proposed decision algorithm is presented in the next section in details.

3.1.2. Distributed Decision Engine

DDE is a distributed event delivery framework based on event producers, event delivery and caching, and event consumers. The central DDE entity is the EventCache, whose basic operations comprise the caching of received events for the duration of their validity and the delivery of the events to the consumers based on subscriptions and delivery policies defined. Before event producers are allowed to feed the EventCache with events, they first need to register the events. The event messages use event ID and type fields for the identification of the event content. For integrity and authentication, the messages use signatures created based on public key cryptography. The reader is advised to refer to [4] for a more detailed introduction on the DDE architecture. The DDE is able to deliver frequently changing information between different types of entities. The event delivery is carried out over TCP transmission. In our scenario, performance monitoring entities provide mobile devices information about the current load in the network and individual access points. In order to carry this out, a DDE EventCache is located in every access network. The performance monitoring entity feeds the EventCache with parameters events carrying information such as the number of users connected, uplink and downlink throughput and packet error rate. The mobile devices capable of doing QoS-driven mobility can use this information to trigger network and base station changes.

3.1.3. Network Information Service

Network information services are specified in the IEEE 802.21 Media Independent Handover (MIH) Services[26] and 3GPP Access Network Discovery and Selection Function[27] (ANDSF) standards. The main purpose of information services is to provide relatively static information about net-works and base stations nearby the mobile device in order to facilitate handover target selection. The information often comprises, e.g., base station location, access technology, frequency band, and overall capabilities. The current standardized information service solutions cannot determine reliably the networks and base stations that cover the current location of the mobile device. Thus, the information service with base station coverage areas introduced in [5] is used in our study to find the optimal handover target network and wireless connection point. The coverage areas are stored as polygons in a geospatial database of the NIS. The mobile device just needs to send its current geographical location coordinates to the NIS and the NIS searches for the networks and base stations that are measured earlier to cover its current location and returns information about them for the decision making of the target. In order to keep the coverage area polygons valid, the database must be dynamic and updated frequently to reflect all changes in the environment and equipment.

3.2. The proposed multi-criteria decision engine

To formalize the operation of our decision engine we use the well-known methodology of Analytical Hierarchy Process (AHP). AHP is a widely used method of multiple-criteria decision making (MCDM) (also referred as multiple-criteria decision analysis, MCDA), which aims at solving compound decisions and planning problems involving multiple criteria. AHP is a structured technique for analysing complex decisions by taking into account many criteria parameters for different alternatives and giving the best matching alternative.

The first step of AHP is the de-composition of the decision problem into a hierarchical structure. The first level presents the goal of the analysis, in this case the selection of the appropriate Wi-Fi access point. Multi criteria parameters (number of discarded packets, delay, and current AP throughput measured on the AP side) are introduced by the second level. The third level contains the alternative choices (available Wi-Fi networks). The result of the AHP process can be calculated in three consecutive steps: computing the pairwise matrices for each criteria and the vector of criteria weights; computing the matrix of option scores, and finally ranking the alternatives. First, AHP creates a pairwise comparison matrix (matrix A), which is an m x m real matrix with the criteria. Each entry of matrix A presents the importance of criteria relative to each other (goes from 1 to 7). In our mHealth scenario, we defined the comparison matrices for two different mHealth service types: one for the HD camera streamer service and another for the application transferring the medically relevant vital signs from patient's smartphone to a hospital/emergency centre. Fig. 2 shows the applied comparison matrices of these two mHealth services. The normalized pairwise comparison Matrix A is derived from Matrix A. The second step is the calculation of the matrix of alternative option scores. The option scores matrix (matrix *S*) indicates the score of the alternatives with respect to the different criteria. The criteria weight vector is built by averaging the entries on each row of normalized matrix A.

$$M_1 = \begin{bmatrix} & a & b & c & d & e & f \\ a & 1 & 1/5 & 5 & 5 & 1/7 & 1/5 \\ b & 5 & 1 & 1/3 & 5 & 1/7 & 1/5 \\ c & 1/5 & 3 & 1 & 5 & 1/7 & 1/3 \\ d & 1/5 & 1/5 & 1/5 & 1 & 1/7 & 1/5 \\ e & 7 & 7 & 7 & 7 & 1 & 5 \\ f & 5 & 5 & 3 & 5 & 1/5 & 1 \end{bmatrix} \quad M_2 = \begin{bmatrix} & a & b & c & d & e & f \\ a & 1 & 5 & 1/3 & 7 & 1/5 & 5 \\ b & 1/5 & 1 & 1/7 & 7 & 5 & 5 \\ c & 3 & 7 & 1 & 7 & 5 & 5 \\ d & 1/7 & 1/7 & 1/7 & 1 & 1/5 & 1/5 \\ e & 5 & 1/5 & 1/5 & 5 & 1 & 1/3 \\ f & 1/5 & 1/3 & 1/5 & 5 & 3 & 1 \end{bmatrix}$$

Fig. 2. Matrix A of high resolution video streaming [left], Matrix A of wearable sensor's data [right]

To obtain the score vectors we calculated averages of entries on each row. Finally, the global score vector is calculated as v = S x w. Thus, the bigger global score indicates the better alternative of the decision problem.

3.3. Signaling framework of the proposed architecture

Fig. 3 presents the operation of our network-assisted Wi-Fi access point selection scheme. The first step according to the proposed signaling framework is the registration of the mHealth application.

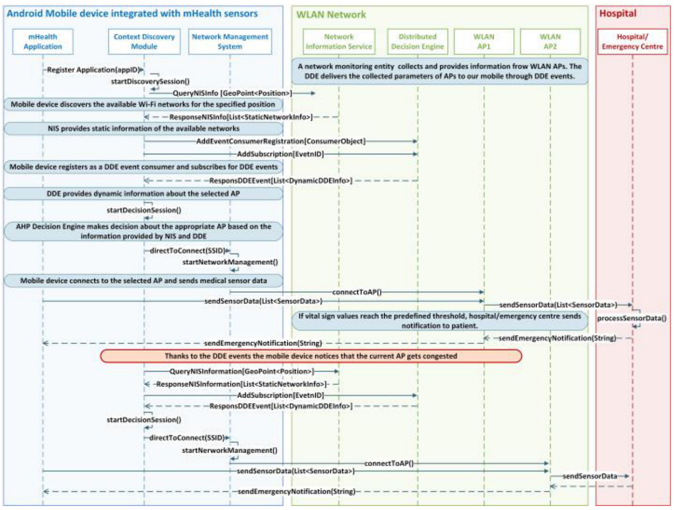

Fig. 3. The proposed network-assisted Wi-Fi discovery and selection scheme

With this step the application notifies our framework to manage the network connections using the smart access point selection scheme. After the registration the algorithm starts the network context discovery session. The Context

Discovery Module (CDM) queries information about the available Wi-Fi networks using NIS, which provides static information of wireless accesses. Based on these parameters the CDM collects dynamic information of the selected network(s) through the DDE events. The most important DDE parameters are throughput in the uplink/downlink, rate of erroneously received and discarded packets, number of discarded packets and number of users, all measured at the Wi-Fi access points. The AHP Decision Engine makes decision about the optimal Wi-Fi AP based on the collected measurement data and directs the Network Management System (NMS) to connect the mobile to the selected network. Fig. 3 presents that in the first phase our Android device is connected to the AP1. The smartphone then notices through the DDE events that the current access point gets congested. The packet loss values of AP1 exceed the predefined threshold. The NMS directs the Android OS to connect to AP2, which provides suitable QoS parameters.

4. Testbed Environment and Measurement Results

4.1. Testbed environment

The measurement story-line focuses on a ubiquitous and real-time patient monitoring situation where two different data sources are used for continuous transmission of patient's vital information from the Body Area Network to the Emergency Centre located in the hospital.

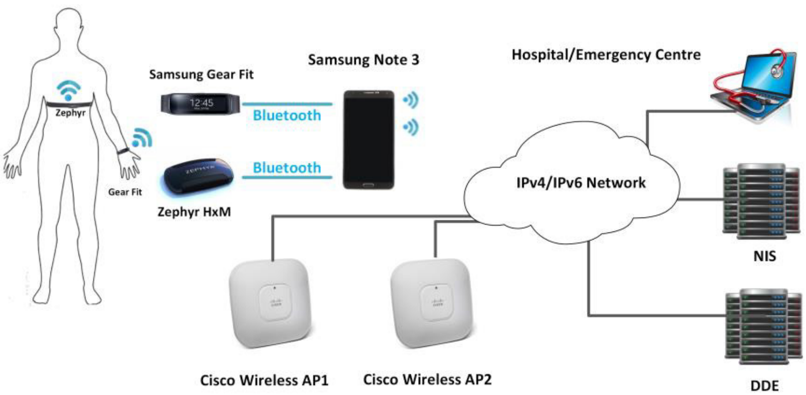

Fig. 4. The proposed testbed environment

The two sources are heart rate information from the Zehpyr HxM and HD live stream from the Smartphone's camera. A Samsung Gear Fit is used to show notifications sent by the hospital/emergency centre. Our Android-based real-time testbed is depicted in Fig. 4. Based on the location information of the mobile device, NIS determines the available Wi-Fi networks in range (access points AP1 and AP2 cover mobile device's current location). The Wi-Fi network provides also services for monitoring the quality of the access points through DDE. There is a network monitoring entity deployed, which collects and provides this information from each AP. Thus, the mobile device subscribes to parameters report event by sending a message to the DDE EventCache in the Wi-Fi network. After that, the mobile device receives parameters events, which cover dynamic information of available Wi-Fi accesses. The smartphone connects to the AP1 based on the decision of the AHP algorithm and starts the HD video stream and the heart rate sensor information transmission.

Based on the DDE events, the mobile device notices that the AP1 is getting congested, measured values exceed the predefined threshold (set to 8% in our measurements), and thus the mobile device queries the NIS and DDE again. The result of AHP shows that AP2 is suitable for our application, so our framework initiates handover execution and the mobile device switches to the AP2. Network-assisted optimized Wi-Fi communication helps to dynamically monitor patient's vital data and also the continuously changing wireless networking parameters, and to perform a highly adaptive mobile communication for better medical QoS/QoE.

4.2. Measurement results

In order to present the efficiency of our framework and to evaluate the proposed multi-criteria decision engine, we designed and implemented two different measurement scenarios. In the first scenario we simultaneously transfer medical sensor data (heart rate values provided by Zephyr HxM), high resolution real-time video stream (using the built-in camera of our Android device) and numerous VoIP flows as background traffic. We measured the delay and packet loss of the currently used AP on the correspondent node which runs and controls the background traffic.

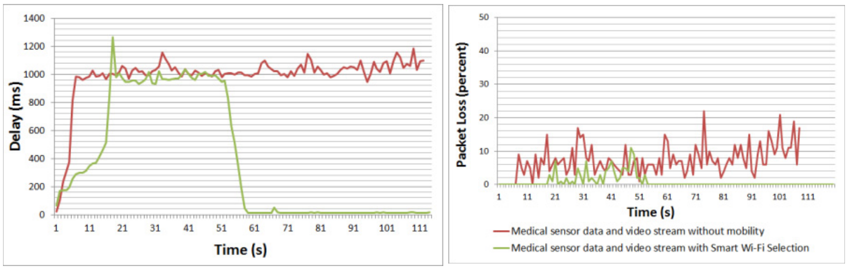

Fig. 5. Delay on AP1 without mobility [red] and with the proposed smart Access Point selection framework [green] (left part), Packet loss in AP1 without mobility [red] and with smart Access Point selection framework [green] (right part)

The left part of Fig. 5 shows that without the proposed smart Access Point selection mechanism the delay is high during the overall measurement session. Using our mHealth framework the Android device is able to detect the inconvenient QoS parameters of AP1 and executes a handover from AP1 to AP2.

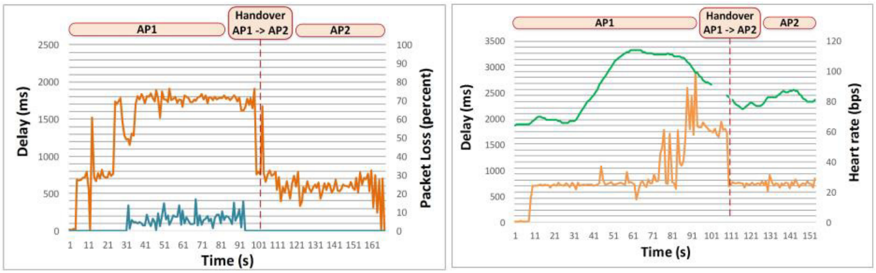

Fig. 6. Delay [orange] and packet loss [blue] (left part), Delay [orange] and heart rate traffic [green] (right part)

In the first period the average delay is high, approximately 1000 ms. However, after the handover from AP1 to AP2 only the background traffic is on AP1, which induces 5-10 ms delay. We limited the capacity of AP1 to 5.5 Mb/s in order to reach the saturation level with less background traffic. The AP2's capacity was 54 Mb/s. We stressed only AP1 with the background traffic. Packet loss values of AP1 in the aforementioned scenario is presented on the right part of Fig. 5. In the second scenario we monitored the delay and packet loss values of AP1 and AP2 on our Android device using the cross-layer feedback information from the DDE events. Based on the measured data the proposed network-assisted smart Access Point selection framework executes handover from AP1 to AP2. The left part of Fig. 6 shows that there is quite high delay and packet loss in AP1, which are not acceptable for the mHealth services. After the packet loss crossed the threshold, our NMS executes a handover from AP1 to AP2. The QoS parameter values of AP2 are suitable for our application, because there are no packet losses and also the delay is normal. The right part of Fig. 6 depicts the communication delay on the currently used AP and also highlights the heart rate data of our biovital sensor. In this scenario we transfer a camera stream and medical sensor data towards to the hospital. Due to the background traffic in AP1, the delay starts to grow continuously. Our framework detects the decreased quality of service and initiates an appropriate handover execution (AP1 to AP2).

Conclusion

In this paper we presented an efficient network-assisted smart Wi-Fi Access Point selection mobility architecture for the ubiquitous applications of Future Internet architectures focusing on real-time, pervasive mHealth services such as multi-sensor based mobile patient monitoring and tele-consultation. The proposed framework is used to select the appropriate available Wi-Fi network using a multi-criteria decision engine, which relies on the Distributed Decision Engine and the Network Information Service. The validation of the proposed integrated mHealth solution was performed on a real-life testbed environment. Results show that our framework and algorithms help to provide medical level QoS/QoE for the quality-sensitive real-time mHealth services.

As a part of our future work we are planning to refine the proposed mobility decision and execution engine to efficiently manage flow level handovers for fine-grained support of diverse mHealth applications in heterogeneous (Wi-Fi, 3G, 4G, etc.) network environments. Also an important task of our future work is the comparison of existing network selection algorithms with our proposed solution.

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References

1. G. Eysenbach, “What is e-health?,” vol. J. Med. Internet Res., 2001.
2. World Health Organization “mHealth-New horizons for health through mobile technologies”, 2011
3. V. Ghini, S. Ferretti, and F. Panzieri, “M-Hippocrates: Enabling Reliable and Interactive Mobile Health Services,” *IT Prof.*, 2012.
4. J. Mäkelä, M. Luoto, T. Sutinen, and K. Pentikousis, “Distributed Information Service Architecture for Overlapping Multiaccess Networks,” *Multimed. Tools Appl*, vol. 55, no. 2, pp. 289–306, Nov. 2011.
5. E. Piri and H. Schulzrinne, “Scaling network information services to support HetNets and dynamic spectrum access,” *Commun. Netw. J. Of*, vol. 16, no. 2, pp. 202–208, Apr. 2014.
6. PWC, *Emerging mHealth: Paths for growth*. 2012.
7. P. Pawar, V. Jones, B.-J. F. van Beijnum, and H. Hermens, “A framework for the comparison of mobile patient monitoring systems,” *J. Biomed. Inform.*, vol. 45, no. 3, pp. 544 – 556, 2012.
8. T. Bratan and M. Clarke, “Towards the Design of a Generic Systems Architecture for Remote Patient Monitoring,” in *Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005. 27th Annual International Conference of the*, 2005, pp. 106–109.
9. PWC, *Touching lives through mobile health, Assessment of the global market opportunity*. 2012.
10. W. D. Bradford, “Telemedicine and Telehealth: Principles, Policies, Performance and Pitfalls by Adam W. Darkins and Margaret A. Cary. Free Association Books, London, 2000. No. of pages 316. ISBN 1-853-43518-X,” *Health Econ.*, vol. 10, no. 7, pp. 681–682, 2001.
11. J. Williams and A. Ellis, *Primary care patients in psychiatric clinical trials: a pilot study using videoconferencing*. BioMed C., 2007.
12. F. Xu, X. Zhu, C. C. Tan, Q. Li, G. Yan, and J. Wu, “SmartAssoc: Decentralized Access Point Selection Algorithm to Improve Throughput,” *Parallel Distrib. Syst. IEEE Trans. On*, vol. 24, no. 12, pp. 2482–2491, Dec. 2013.
13. M. F. Tuysuz and H. A. Mantar, “Network-assisted QoS-based fast handover with smart scanning over IEEE 802.11 WLANs,” in *Personal Indoor and Mobile Radio Communications (PIMRC), 2013 IEEE 24th International Symposium on*, 2013, pp. 2946–2950.
14. J.-C. Chen, T.-C. Chen, T. Zhang, and E. van den Berg, “WLC19-4: Effective AP Selection and Load Balancing in IEEE 802.11 Wireless LANs,” in *Global Telecommunications Conference, 2006. GLOBECOM ’06. IEEE*, 2006, pp. 1–6.
15. J. Makela and K. Pentikousis, “Trigger Management Mechanisms,” in *ISWPC ’07*, 2007.
16. M. Luoto and T. Sutinen, “Cross-Layer Enhanced Mobility Management in Heterogeneous Networks” in *Communications, ICC’08, 2008*
17. P. Pawar, B.-J. van Beijnum, K. Wac, H. Hermens, and D. Konstantas, “Towards Location Based QoS-Aware Network Selection Mechanism for the Nomadic Mobile Services,” in *Consumer Communications and Networking Conference, 2009.*, 2009.
18. L. Bokor, G. Jeney, and J. Kovács, “A Study on the Performance of an Advanced Framework for Prediction-based NEMO Handovers in Multihomed Scenarios,” *INFOCOMMUNICATIONS J. VI*, pp. 16–27, 2014.
19. A. Dutta, S. Chakravarty, K. Taniuchi, V. Fajardo, Y. Ohba, D. Famolari, and H. Schulzrinne, “An Experimental Study of Location Assisted Proactive Handover,” in *Global Telecommunications Conference, 2007. GLOBECOM ’07. IEEE*, 2007, pp. 2037–2042.
20. E. Piri, “Cell Coverage Area Information Service to Improve Cell Se-lection in HetNets,” presented at the CCNC, Las Vegas, USA, 2014.
21. E. Piri, “Road Based Mobility with Network Information Services,” *Procedia Comput. Sci.*, vol. 40, no. 0, pp. 198 – 205, 2014.
22. E. Piri, M. Varela, and J. Prokkola, “A Network Information Service for Quality-Driven Mobility,” presented at the CCNC, USA, 2015.
23. N. Varga, L. Bokor, and A. Takács, “Android-based Testbed and Demonstration Environment for Cross-layer Optimized Flow Mobility,” in *TridentCom’2014, May 5–7, 2014 Guangzhou, People’s Republic of China*, 2014.
24. N. Varga, L. Bokor, S. Bouroz, B. Lecroart, and A. Takács, “Client-based and Cross-Layer Optimized Flow Mobility for Android Devices in Heterogeneous Femtocell/Wi-Fi Networks,” *Int. Conf. Sel. Top. Mob. Wirel. Netw.*, Sep. 2014.
25. N. Varga, L. Bokor, and A. Takacs, “Context-aware IPv6 Flow Mobility for Multi-Sensor based Mobile Patient Monitoring and Tele-consultation,” in *2014 First International Workshop On Wireless Solutions For Healthcare Applications (Concerto 2014)*, Italy, 2014.
26. IEEE, *IEEE Standard for Local and metropolitan area networks- Part 21: Media Independent Handover*. IEEE, 2009.
27. 3GPP TS 24.312, *Access Network Discovery and Selection Function (ANDSF) Management Object (MO), Rel. 11*. 2013.